Development of a Low-Cost Highly Flexible Re-entry Platform

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Introduction

Overview

With a growing interest in atmospheric entry, descent, and landing research as well as the necessity to empirically test increasingly complicated entry systems, a growing need for a quick and cost-effective method of experimentation is needed. The Hypersonic Configurable Unit Ballistic Experiment is a test and evaluation platform allowing for in-situ research and rapid testing of novel technologies in a re-entry environment. HyCUBE takes the form of a small satellite-sized re-entry vehicle and, with the additional space on board the vehicle, can act as a platform for testing novel guidance and control methodologies.

HyCUBE's Objectives:

- Perform a controlled atmospheric re-entry of a small satellite-sized re-entry vehicle by deploying an exobrake.
- Survive peak heating with a thermal protection system (TPS).
- Record observation of hypersonic conditions to meet mission specific science objectives.
- Perform in-flight noise resistant GPS denied attitude determination.
- Transmit data using Iridium's satellite constellation before splashdown

Concept of Operations

Being deployed from its cube satellite dispenser after the re-entry burn of the launch vehicle's second stage, HyCUBE will immediately be on a re-entry trajectory. This simplifies:

- Design of mission longevity
- Re-entry license approval
- Ride share orbit deployment compromises

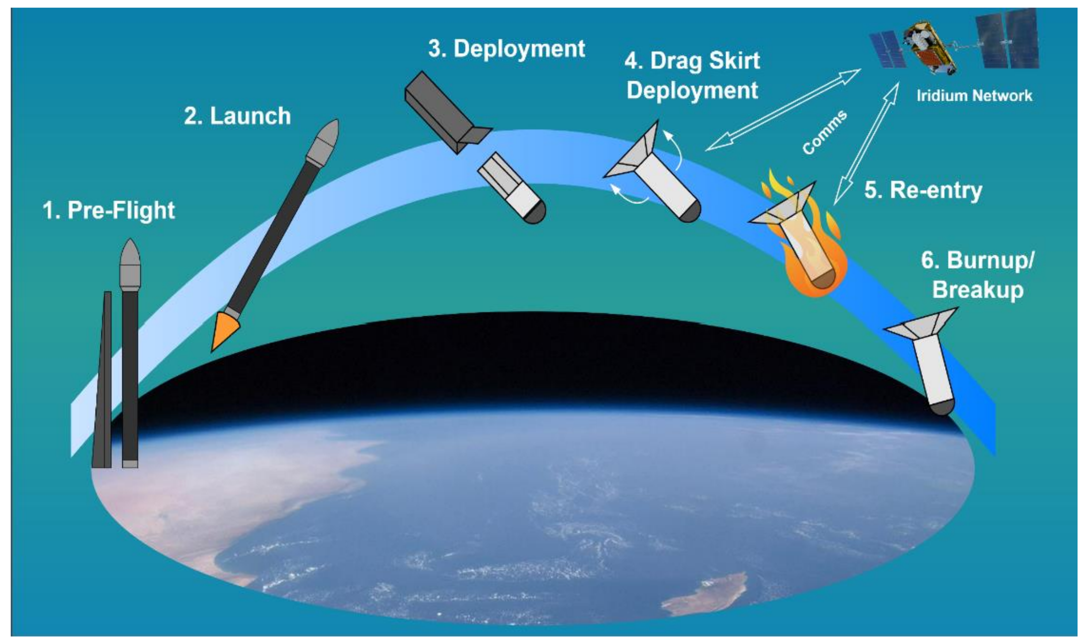

Figure 1: Overview of phases of operation during lifecycle of HyCUBE mission. Illustrated by Vincent Twin.

System Architecture

Structure

The initial iteration of HyCUBE will be constructed as a tube deployed re-entry vehicle (TDRV) with a diameter of 7cm. The nose cone will consist of a hemisphere geometry constructed of AETB with embedded sensors. The drag skirt is formed from Nextel fabric coated in RTV.

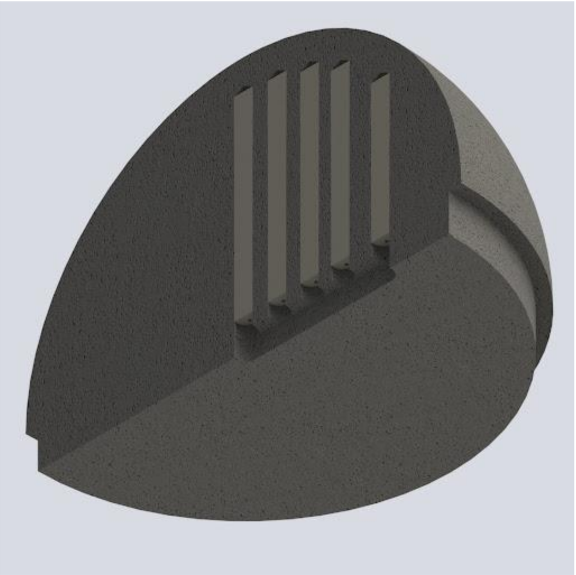

Figure 2: Cross-sectional view of TDRV nosecone with embedded type-K thermocouples. The final layout of thermocouples is still in development.

Data Link

Two Iridium 9602 modems will serve as the mission's datalink. These modems connect to 2 patch antennas located on the side of the TDRV and a helical antenna positioned on the rear. Once connection is resumed after re-entry, the system should be capable of 2.4 Kbps data transmission.

Avionics

An onboard Cortex M4 microcontroller will be responsible for interfacing with multiple thermocouples, an IMU, and a GPS. In addition, it will run instrumentation flight code and attitude determination algorithms.

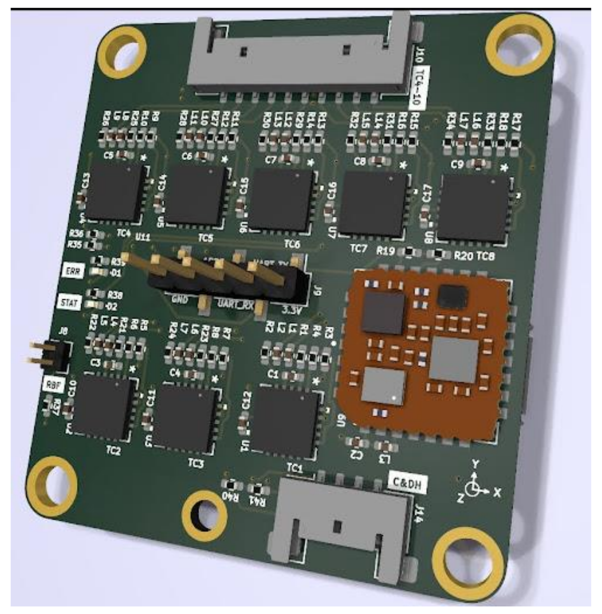

Figure 3: Topside view of avionics board. Dimensions of board are 41mm x 45mm and is identical to that of the Iridium 9602 modems. A uniform and compact board size assists with the TDRV's volume limitations.

State Reconstruction

The measurements from the onboard GPS, IMU, and magnetometer will be used to compute estimated vehicle states for the duration of re-entry. During portions of re-entry, GPS is blocked and interference will increase measurement noise in the magnetometer.

Simulation

Trajectory Simulation

The trajectory of HyCUBE was modelled based off initial conditions assuming launch vehicle second stage deployment. Preliminary 3 degree of freedom simulation show that the TDRV will pass through the region of interest.

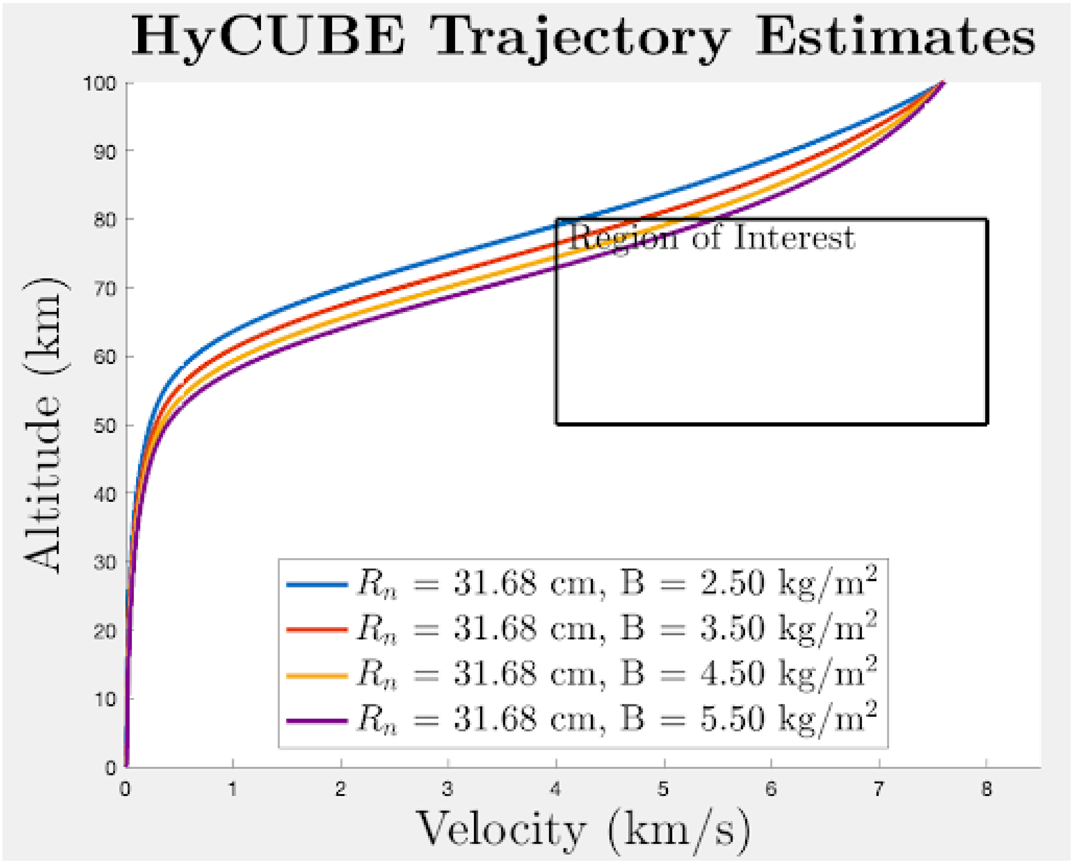

Figure 4: Trajectory estimation for HyCUBE missions with varying ballistic coefficients. It is assumed that the drag skirt remains intact over duration of re-entry.

Thermal Simulation

As will all re-entry vehicles, thermal considerations dominate. The heat load of HyCUBE was approached by generating a stagnation temperature estimate over time based off the 3 degree of freedom trajectory simulation (Figure 5). Afterwards, a CFD simulation was performed to find the estimated temperature profile of the nose cone at various points in its trajectory (Figure 6).

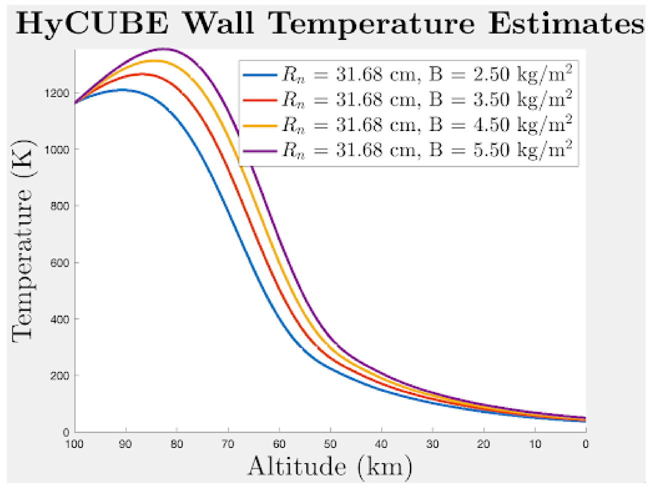

Figure 5: Stagnation point wall temperature estimation based on trajectory from figure 4.

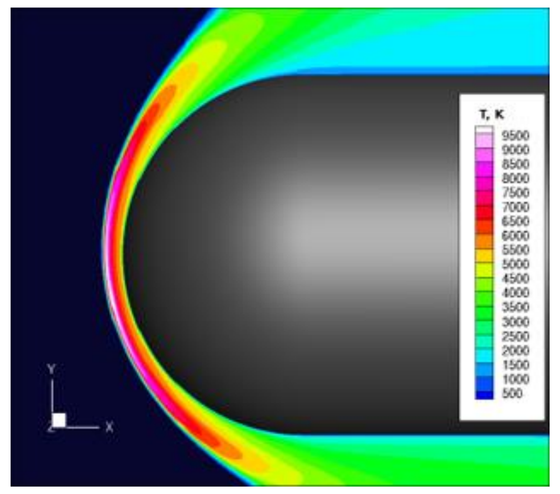

Figure 5: CFD simulation of TDRV nosecone. Simulated by Alice Lowenson & Ioannis Nompelis

Science Matrix

	Objectives
Plasmatron Test	Characterize response of TPS under re-entry like conditions
	Verify accuracy of temperature and heatflux sensors
	Characterize response of sapphire window
	Characterize durability of drag skirt to re-entry like conditions
Spin Test	Characterize re-entry like data link
	Validate antenna configuration
	Generate IMU and GPS data set to validate State reconstruction algorithms
EDU Test	Serves as a instrumentation prototype
	Allow for testing of instrumentation flight code
	Characterization of state reconstruction algorithms
TES-19	Validate re-entry survivability
	Measure in-flight thermal load and sensor output
	Characterize in-flight data link
TES-20	Implement improvements from TES-19
	Measure low resolution plasma spectra
	Test data link under higher message size
TES-21	Test larger TDRV form factor
	Characterize medium resolution spectrometer
	Verify payload platform for future missions

Conclusion

As shown in this poster, a hypersonic re-entry testbed platform such as HyCUBE will not only be useful but realistic. Development work is currently taking place to ensure that its first mission, TES-19, will occur without issue.

Acknowledgements

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